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[54] **CRANK SHAFT AND METHOD OF MANUFACTURING THE SAME**

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[63] Continuation of Ser. No. 852,219, May 28, 1992, abandoned.

[30] **Foreign Application Priority Data**

Nov. 20, 1990 [JP] Japan 2-316561

[51] **Int. Cl.**⁶ **F16C 3/04**

[52] **U.S. Cl.** **74/595**; 74/597; 427/248.1

[58] **Field of Search** 74/595–598, 74/600

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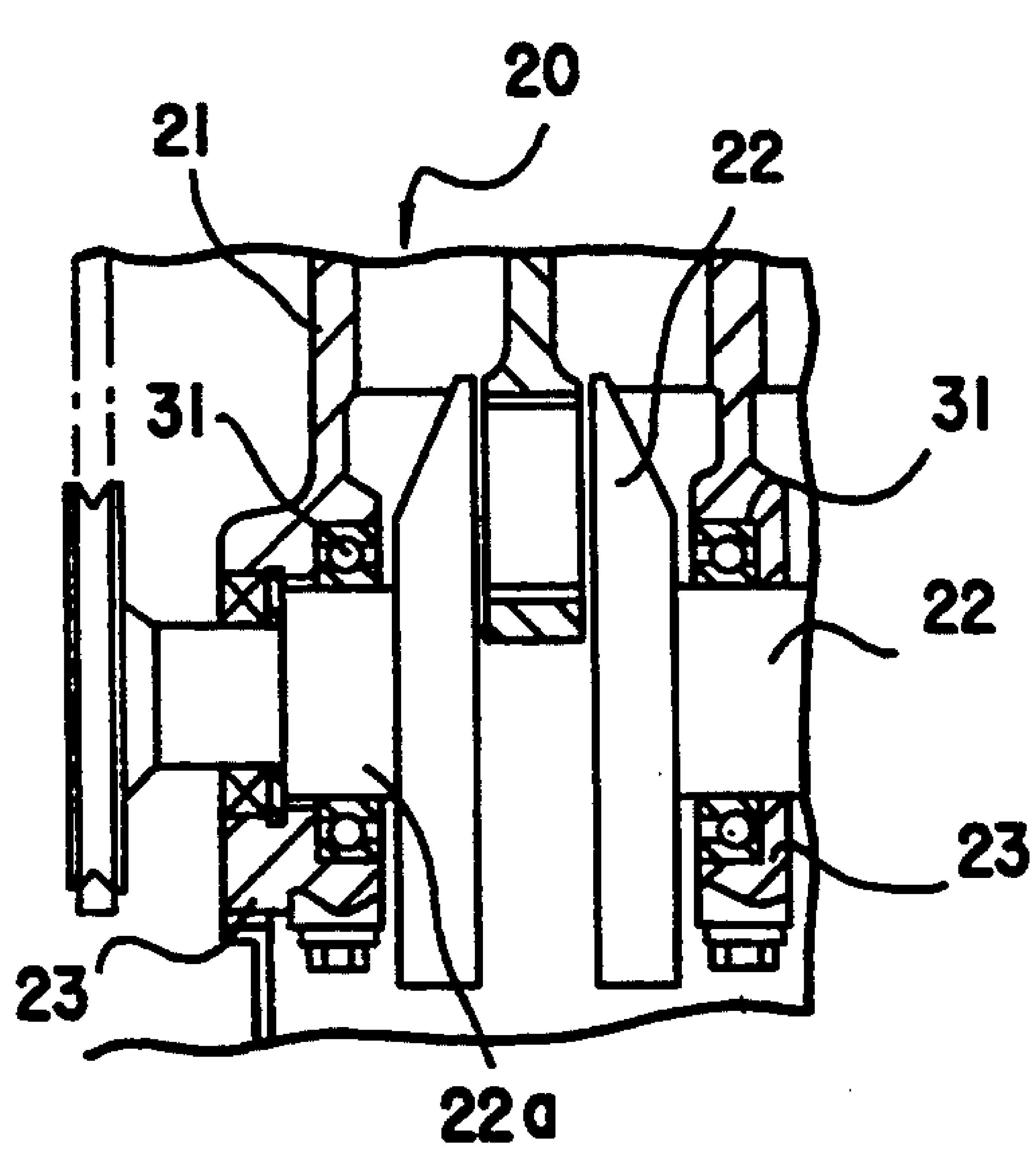
[57] **ABSTRACT**

A crank shaft is constructed only at the surface layer of a journal portion with a hard nitride layer, so that the resultant crank shaft is available at a low cost, not so heavy and excellent in durability in comparison with a case employing a hard material for the whole crank shaft. Also, a method of manufacturing a crank shaft according to the present invention employs fluorinating process prior to nitriding process to change a passive coat layer, such as oxide layer on the surface of the journal portion to a fluoride layer, which protects the same surface. Therefore, even when there is space of time between formation of fluoride on the surface of the journal portion and nitriding process, the fluoride layer protects and keeps the surface of the journal portion in a favorable condition, resulting in that re-formation of oxide layer on that surface is prevented.

4 Claims, 3 Drawing Sheets



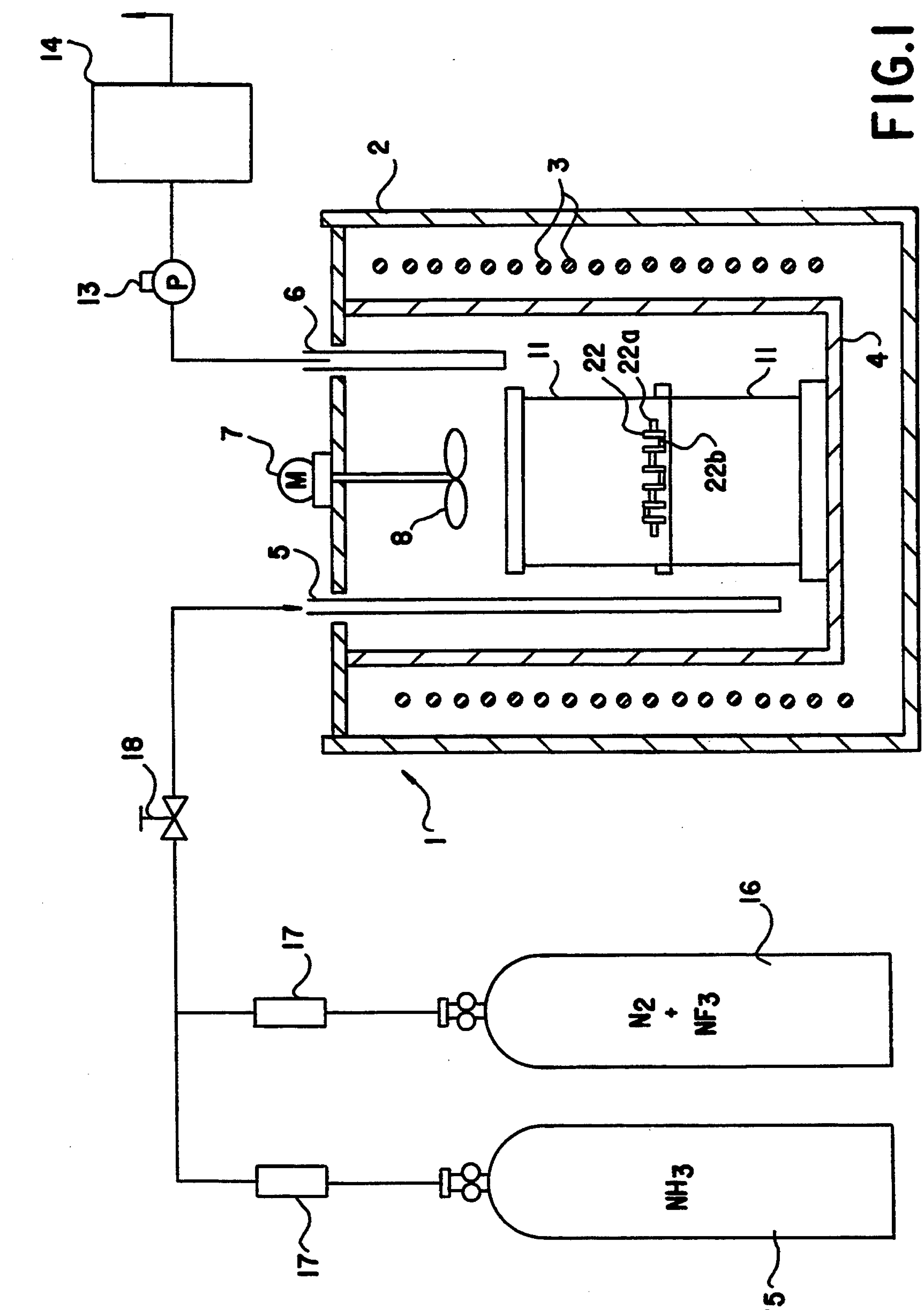


FIG. 1

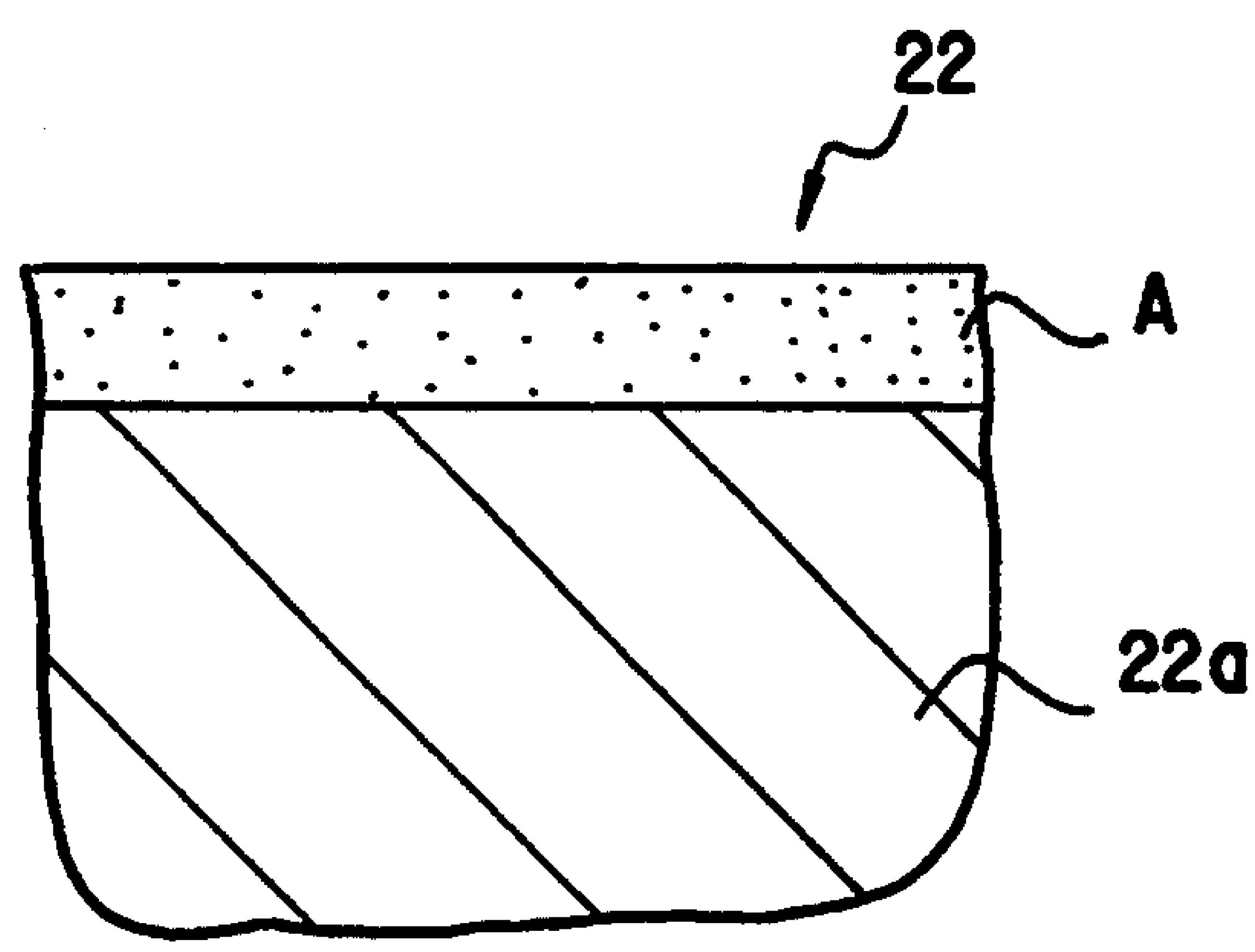


FIG.2

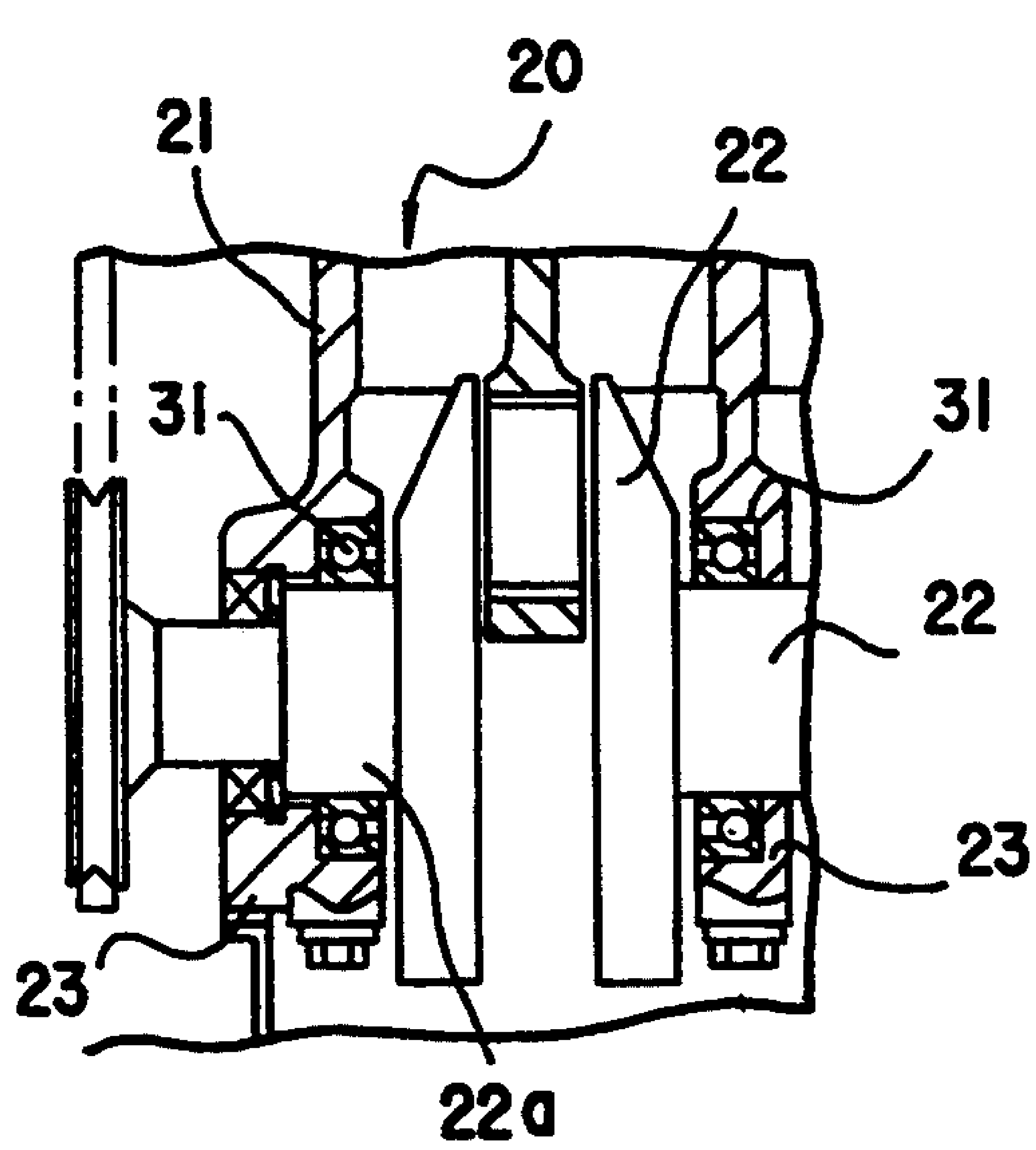


FIG.3

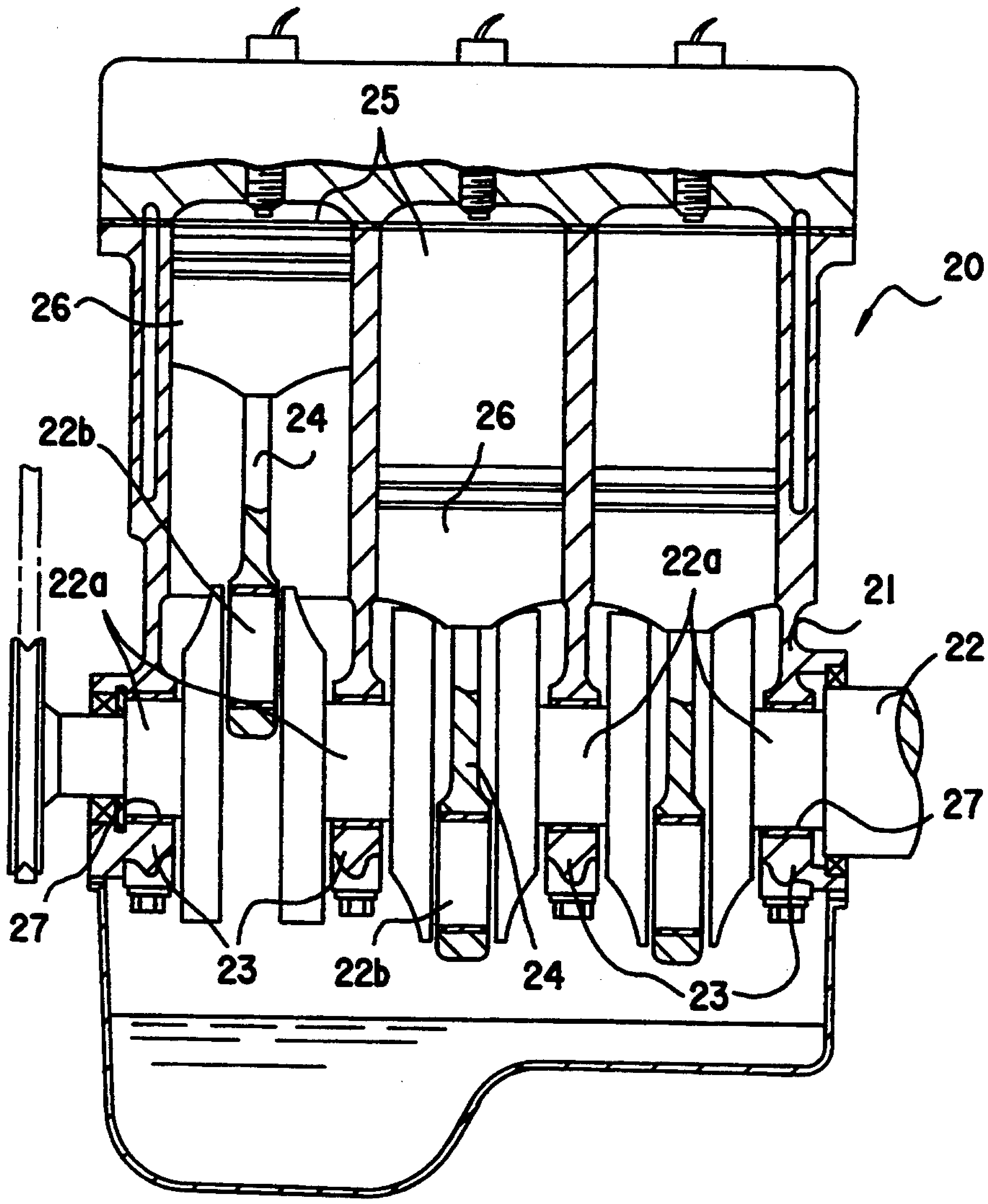


FIG.4

CRANK SHAFT AND METHOD OF MANUFACTURING THE SAME

This application is a continuation of application Ser. No. 07/852,219, filed on May 28, 1992 now abandoned.

FIELD OF THE INVENTION

The subject invention relates to a crank shaft of which a journal portion is formed with a hard nitride layer so as to have remarkably improved properties such as durability and also to a method of manufacturing the crank shaft.

BACKGROUND OF THE INVENTION

Generally, a crank shaft **22** for engine is, as shown in FIG. **4**, rotatably supported at its journal portions ***22a*** by bearings **23** provided in a crank case **21** of engine **20**. Pins ***22b*** are connected with connecting rods **24** a manner of being freely rotatable, so that a force applied to the crank shaft **22** tends to cause the crank shaft **22** to be bent around the bearings **23** when a piston **26** is moved down due to an explosion in a combustion chamber **25**. Therefore, the journal portions ***22a*** in association with bearing metals **27** of the bearings **23** are required to have high durability.

Hence, specific kinds of steel materials having high durability are selected for the crank shaft **22** to improve durability at its journal portions ***22a***. This, however, leads to problems such as an increase in the cost of materials and in weight.

The present invention has been designed to overcome the above problems. An object of the present invention is to the improve the durability of the journal portions of the motor rotary shaft without an increase in the cost of materials and in weight.

SUMMARY OF THE INVENTION

To achieve the above object, the invention of this application is directed to a crank shaft having a journal portion whose surface layer includes a hard nitride layer. To provide such hard nitride layer, the invention is also directed to a manufacturing method for a crank shaft wherein the journal portion of the crank shaft is held in a fluorine- or fluoride-containing gas atmosphere under a heated condition and a fluoride layer is formed on the surface of the journal portion. Thereafter, such journal portion is held in a nitride atmosphere under a heated condition and a hard nitride layer is formed on the surface of the journal portion.

In detail, the crank shaft of the present invention is constructed, at the surface layer of the journal portion, with a hard nitride layer but does not employ a hard material for the whole crank shaft, thereby providing a crank shaft at a low cost, which is not heavy and is excellent in durability. In the manufacturing of the crank shaft, the journal portion of the shaft is first held in a fluorine- or fluoride-containing gas atmosphere, under a heated condition, to form a fluoride layer on the surface of the journal portion, and is then held in a nitride atmosphere, under a heated condition, to remove the formed fluoride layer from the surface of the journal portion and simultaneously form a hard nitride layer on surface of the journal portion from which the fluoride layer is removed as such fluoride layer is being removed. The formation of fluoride layer on the surface of the journal portion is carried out before nitriding to purify and, at the same time, activate the surface of the journal portion, so that the nitride layer can be uniformly and rather deeply formed on the surfaces of the journal portion. Thus, the hard nitride later can be uniform and thick in thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic sectional view showing a heat treatment furnace used in an example of the present invention,

FIG. **2** is a sectional view showing a condition of a nitride layer formed on a journal portion of a crank shaft, and

FIGS. **3** and **4** are sectional views showing principal parts of engines provided with respective crank shafts.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, details of the present invention are described below.

The fluorine- and fluoride-containing gas to be used for fluorinating process in the present invention is an inactive gas, such as N_2 containing at least one of the fluorine source components, such as NF_3, BF_3, CF_4, HF, SF_6, and F_2. NF_3 is most preferable and useful in respect of reactivity, handling properties, and the like for the purposes of the invention.

In the nitriding process of the manufacturing method according to the present invention, the crank shaft made of a steel such as stainless steel, and with the portions of the shaft other than the journal portion being masked by a coating of a known anti-hardening agent and the journal portion held, as aforementioned, in the fluorine- or fluoride-containing gas atmosphere under a heated condition at 250° to 400° C. when NF_3 is used, for example, to form fluoride layer on the surface of the journal portion. Thereafter, the journal portion is subjected to nitriding (or carbon nitriding) using a known nitriding gas such as ammonia. The concentration of the fluorine source components such as NF_3 in the fluoride gas is, for example, 1000 to 100000 ppm, preferably 20000 to 70000 ppm and most preferably 30000 to 50000 ppm. The time for holding the journal portion in the fluorine- or fluoride-containing gas may be selectively set corresponding to kinds of steel materials, shapes and sizes of the crank shaft, heating temperatures or the like and it is generally a few minutes or scores of minutes.

The manufacturing process of the present invention will be further detailed. A journal portion ***22a*** of a crank shaft **22** shown in FIG. **4** which is made of steel and masked at portions such as ***22b*** other than the journal portion may be so as to be degreased and then placed in a heat treatment furnace **1** as shown in FIG. **1**. The heating furnace **1** is a pit furnace comprising an outer shell **2**, a heater **3** provided therein and an inner container **4** disposed inside the heater **3**. A gas guide line **5** and an exhaust pipe **6** are inserted into the pit furnace. Gas is fed to the gas guide line **5** from cylinders **15** and **16** through a flow meter **17** and a valve **18** and the like. The atmosphere inside the pit furnace is agitated by fan **8** which is rotated by a motor **7**. The crank shaft **22** is held in a metallic container **11** to be placed in the furnace. In the drawing, reference numeral **13** denotes a vacuum pump and **14** denotes a noxious substance eliminator. Fluorine- or fluoride-containing gas, for example a mixed gas of NF_3 and N_2, is injected into the furnace and heated to a predetermined reaction temperature. NF_3 generates active fluorine at 250° to 400° C., so that organic and inorganic contaminants on the surfaces of the journal portion **22a** are removed. The generated fluorine simultaneously is reacted with Fe, chrome substrate or oxides such as FeO, Fe_3O_2, and Cr_2O_3 on the surface of the journal portion **22a** as represented in the following reaction formulae, thereby forming on the surface of the journal portion **22a** a quite thin fluoride layer containing therein such compounds as FeF_2, FeF_3, CrF_2, and CrF_4.

$$FeO+2F \rightarrow FeF_2+1/2O_2$$

$$Cr_2O_3+4F \rightarrow 2CrF_2+3/2O_2$$

The reaction changes the oxide layer on the surfaces of journal portion **22a** to a fluoride layer and removes O_2 adsorbed on the same surface. The fluoride layer is stable at temperatures below 600° C. when there exists no O_2, H_2O, to thereby prevent formation of an oxide layer and adsorption of O_2 on and by the metallic substrates. Also, according to the fluorinating process, the fluoride layer is formed on the surface of the furnace material at the initial stage, so that the fluoride layer thereafter prevents possible damage to the surfaces of the furnace material due to application of fluorine- or fluoride-containing gas. The journal portion **22a** duly treated with fluorine- or fluoride-containing gas is further heated to a nitriding temperature of 480° to 700° C. and applied in this state with NH_3 gas or a mixed gas of NH_3 and a gas containing carbon sources (such as RX gas), whereby the aforesaid fluoride layer is reduced or broken by H_2 or trace amount of water as represented by the following formulae, thereby causing the active metallic substrates to be formed and exposed.

$$CrF_4+2H_2 \rightarrow Cr+4HF$$

$$2FeF_3+3H_2 \rightarrow 2Fe+6HF$$

Simultaneously with formation of the activated metallic substrates, active N atoms enter and disperse in the metal. As a result, a solid compound layer (nitride layer) containing such nitrides as CrN, Fe_2N, Fe_3N, and Fe_4N is formed on the surfaces of the metallic substrate. Then, the foregoing masking of the rotary shaft **22** is duly removed.

The conventional nitriding process forms similar nitride layers to the above but it has a lower activity on the substrates surfaces due to oxidized layer formed thereon during elevation of temperatures from normal room temperatures to nitriding temperatures or O_2 adsorbed at that time, so that the degree of adsorption of N atoms on the substrates surfaces is low and not uniform. The non-uniformity is increased also by the fact that it is practically impossible to keep the degree of decomposition of NH_3, uniformly in the furnace. According to the manufacturing process of the present invention, adsorption of N atoms on the surface of the journal portion **22a** is carried out uniformly and quickly to thereby prevent the above problem while providing the solid nitride layer.

The resultant crank shaft **22** in which the surface layer of its journal portion **22a** includes a hard nitride layer A as shown in FIG. **2** is thereby excellent in durability.

An engine **20** shown in FIG. **3** is substantially identical with that of FIG. **4** except that it uses a ball bearings **31** for the bearings of the crank shaft **22**. In this case, the ball bearing **31** (particularly the rolling member, such as balls, and ball races) are nitrided together with the journal portion **23** of said crank shaft **22** by the nitriding process according to the present invention, whereby the ball bearings **31** themselves can be reduced in frictional resistance and further rigidly fitted to the journal portions **22a**.

The nitriding process of the manufacturing method according to the present invention may be applied to the whole crank shaft **22**, not merely to the journal portion as referred to in the above example.

Although steel is used for the crank shaft in the above-mentioned example, metallic materials other than steel such as aluminium and titanium may be used for the crank shaft and the same effect as above can be obtained.

As seen from the above, the crank shaft of the present invention is constructed such that the surface layer of the journal portion has a hard nitride layer but does not employ a hard material for the whole crank shaft. Consequently, a crank shaft is obtainable at a low cost, and which is not as heavy and is excellent in durability. Also, the crank shaft of the present invention can reduce in resistance to sliding to about one third with the solid nitrided layer, and thereby realize a saving of the coolant or the like. Furthermore, as above-mentioned, in the manufacturing method according to the present invention, the fluorinating is carried out before the nitriding process to change the passive coat layer such as the oxide layer on the surface of the journal portion to a fluoride layer which protects the same surface. Therefore, even when there is interval of time between the formation of fluoride layer on the journal portion and the nitriding process, the fluoride layer protects and keeps the surface of the journal portion in a favorable condition such that reformation of oxide layer on that surface is prevented. The fluoride layer is then decomposed and removed in the subsequent nitriding process to cause the surface of journal portion to be exposed. Since the exposed metal surface is activated, N atoms in the nitriding process readily, deeply and uniformly disperse into the journal portion, thereby forming the surface layer of the journal portion into a thick and uniform hard nitrided layer.

Next, the present invention will be further described according to an example.

EXAMPLES

Journal portions and pins of a crank shaft ($300\times\phi$ 25 mm) made of SUS316 stainless steel were washed with trichloroethane. The washed shaft was masked at its portions other than the journal portions and pins and then placed in a heat treatment furnace **1** as shown in FIG. **1** to be held in N_2 gas atmosphere containing 5000 ppm of NF_3 at 300° C. for 15 minutes. This treatment was followed by heating to 530° C. and introducing a mixed gas of 50% of NH_3+50% of N_2 into the heat treatment furnace **1** to perform nitriding of the shaft for a period of 3 hours. Then, the crank shaft was air-cooled and taken out of the furnace. The thickness of the nitride layer of the journal portion and pins of the crank shaft were 10 to 70 μm, and the surface hardnesses of the nitride layers were 1000 to 1350 Hv and the hardness was substantially higher than that obtained by the conventional nitriding method.

What is claimed are:

1. A crank shaft of a base material containing Fe and Cr and having a journal portion, a surface of the journal

portion having a hard nitride layer of a surface hardness of 1000 to 1350 Hv and a thickness of 10 to 70 μm, the crank shaft further including portions other than the journal portion which do not have the hard nitride layer on a surface, the hard nitride layer on the journal portion being formed on the surface of the base material by providing a fluoride layer on the surface which includes reaction products of fluorine and the Fe and Cr contained in the base material, removing the fluoride layer to expose the base material, and then nitriding the surface.

2. A crank shaft according to claim **1**, wherein only the journal portion of the crankshaft has the hard nitride layer.

3. A crank shaft according to claim **1**, wherein the base material of the crankshaft contains a metallic material selected from the group consisting of steel, aluminum and titanium.

4. A crank shaft according to claim **1**, wherein the base material of the crankshaft contains stainless steel.

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